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Basic Research in Human Factors

Stanley Deutsch and Elizabeth F. Neilsen
Committee on Human Factors
National Research Council

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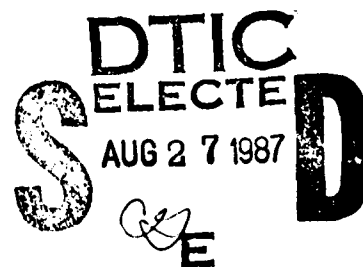
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Six studies are in various stages of completion in the CORE program of the Committee on Human Factors. Preliminary drafts of reports on integrated ergonomic modeling, human performance models, mental models, and multicolored displays have been prepared and are currently in the prepublication review process. In addition, reports of the workshop on distributed decision making and the seminar on expert systems, both convened in late 1986, are being drafted. The technical plans have been completed for a panel meeting on human (Continued)		

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20. ABSTRACT (Continued)

factors issues for an aging population. The committee is in the process of specifying its research agenda for the next study period.)

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Research Note 87-35

**NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
COMMISSION ON BEHAVIORAL AND SOCIAL SCIENCES AND EDUCATION**

COMMITTEE ON HUMAN FACTORS

Annual Technical Report on

**Grant No. N00014-85-G-0093
BASIC RESEARCH IN HUMAN FACTORS**

**Stanley Deutsch, Study Director
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SUMMARY

The Committee on Human Factors was established in 1980 in the Commission on Behavioral and Social Sciences and Education by the National Research Council at the request of a consortium of five major government agencies. The purposes of the committee are to provide guidance and recommendations for the support of basic research relevant to the discipline of human factors by these government organizations, to serve as a mechanism for interdisciplinary communication, to encourage the participation of scientists in conducting basic investigations relevant to major theoretical and methodological issues, and to respond to the needs of sponsors for advice on specific issues relating to their research programs.

During 1986, over 80 scientists, representing a wide variety of disciplines, have contributed their expertise on a voluntary basis to the various activities of committee's CORE Program. The committee continued the working group meetings studying human performance modeling, held workshops on mental models, distributed decision making, and expert systems, and convened a steering group to plan a study on aging. The committee continued to oversee work on the reports of studies on human performance modeling, integrated ergonomic models, multicolored displays, and mental models. Preliminary drafts of these reports are currently being revised based on the comments of peer reviewers. These reports are scheduled for publication in 1987.

INTRODUCTION

The Committee on Human Factors in the Commission on Behavioral and Social Sciences and Education was established as a standing committee by the National Research Council in 1980. During the current reporting period, the Committee has been sponsored by five government agencies: the Cognitive and Neural Sciences Division of the Office of Naval Research, the Directorate for Life Sciences in the Air Force Office of Scientific Research, the Directorate for Basic Research in the Army Research Institute, the Automation and Human Factors Division in the National Aeronautics and Space Administration, and the Directorates for the Behavioral and Neural Sciences and for Information, Robotics, and Intelligence Systems in the National Science Foundation.

OBJECTIVES

The mandate of the Committee on Human Factors is to:

- * advise its sponsors regarding the most important basic research needs in human factors engineering and provide guidance on methods for investigating such problems;
- * explore in depth the state of knowledge in selected areas judged to be of particular importance as a basis for the development of detailed research agendas;

- * provide a mechanism for encouraging contact and communication among both basic and applied researchers in the field in the United States and abroad;
- * interest outstanding young and senior scientists outside the field of human factors in conducting basic research relevant to major theoretical and methodological issues;
- * be responsive to sponsors' requests for advice on specific problems or issues relating to their human factors research programs.

MEMBERSHIP

The members of the committee are selected on the basis of their expertise as demonstrated by their contributions to the advancement of science in their areas of specialization. The scientists who are committee members constitute a broad balanced representation of the human factors and related disciplines. Each of these experts serves on the committee or its subgroups without reimbursement other than for travel expenses related to committee activities. (The committee members are identified in Appendix A.) More than 80 subject matter experts served on the various CORE Program working groups, workshops, and seminars during 1986-1987 without compensation. (See Appendix B.)

ACTIVITIES DURING THE PAST YEAR

MEETINGS

In 1986, the Committee on Human Factors held three meetings: January 23-24, May 1-2, and September 18-19. The committee reviewed the reports in process and provided management guidance and oversight in 1986 for the activities of one working group, one panel, three workshops, and two seminars. The members reviewed the reports in preparation and proposed new studies for consideration starting in 1987.

In addition to the committee meetings, the following technical sessions were convened in 1986: working group on human performance modeling, workshop on distributed decision making, seminar on expert systems, planning meetings for the panel for the studies on aging and project productivity, and report writing sessions for integrated ergonomic modeling and multicolored displays. (The purposes and status of these studies are described below.) In addition, two meetings were held with the sponsors to provide status reports and discuss plans for future studies.

STUDIES IN PROGRESS

Human Performance Models:

Models can serve a number of purposes in human factors engineering. They can reduce development time by providing predictions which limit the design domain that must be explored empirically; they may be used as design tools by system developers; they can provide a normative base against which to evaluate particular human performance; and they can promote communication between the design engineer and the behavioral specialist. Micro models have been constructed to represent elements of human performance. However, the need exists for larger scale models that are readily adaptable at the system level.

Progress over the past fifteen years has provided the ability to represent analytically, either in mathematical or analog form, selected aspects of integrated human performance. Several of these include the Optimal Control Model (OCM) that has been developed to describe the manual control of piloted vehicles, the SAINT simulation language that is designed to represent human task performance in a simulator, and the Human Operator Simulator (HOS) that permits the integration of elementary models into larger task-related descriptors of human performance.

However, the state of model development for large-scale multiperson systems remains crude. For many human activities, behavior is understood at a level which admits only simple taxonomies or verbal-analytic models.

At the opposite end of the spectrum, if a task is sufficiently defined, it is always possible to build a computer program which will produce the same output as a specific task execution sequence performed by a particular individual. Such a program is only of interest, however, if it can be extrapolated to predict individual performance when system variables are changed. Such generalization has been achieved only in limited task contexts. In terms of the range of behavior and task situations which can be described with useful generality, there is a continuing requirement to narrow the gap between verbal analytic representations and predictive models. In addition to the need for generation of such models, there are also methodological issues to consider. For example, what is the proper modeling framework? What methods and procedures should be used for validation? What are the acceptable degrees of freedom for the parameters of such a model?

The working group has reviewed current studies on macro models and has identified research needed for the description and prediction of human performance. Its report, which will recommend research studies to enhance the ability to represent integrative human performance analytically as a guide to system design, is scheduled for publication in 1987.

Multicolored Displays:

Over the past decade, with the growing sophistication of microelectronic processing and digital computation technology, there has been a concurrent increase in the use of color displays. Multicolored displays are used increasingly in a variety of civilian and military systems including

aircraft, ships, and command, control and communication centers. These displays have a number of advantages relative to monochrome or black and white displays. Color provides an additional dimension for coding, spatially confused graphical or text information can be grouped or segregated, ranges of quantitative values can be differentiated easily, and critical features can be highlighted. Furthermore, the addition of color to otherwise achromatic displays provides interest, aesthetic appeal, and some measure of perceived realism. The addition of color also appears to provide the user with greater sensitivity to the subtleties of display content.

However, multicolored displays are not inherently necessary or useful for all applications. It is argued that color has been indiscriminately added for the sake of technology and not for the benefit of the user. The inappropriate addition of color to otherwise achromatic or monochromatic displays may degrade the utility of the display, leading to reduced user performance. There are other problems associated with these displays which can offset their advantages. Relative to monochrome or black and white display, a multicolored display is more expensive, maintenance requirements are greater, there is some sacrifice of display resolution, and an increased probability of certain kinds of human errors.

At a two-day workshop, the current uses of color in visual displays were categorized along three dimensions: display content, purpose of color in the display, and display dynamics. Representative examples of display designs relative to these categories were discussed, along with applicable

questions relating to color selection, design of color systems, and visual implications of display design. In addition, representative research issues and findings that are central to the selection and use of color in various types of displays were addressed. A report containing research recommendations pertinent to the general and specific uses of multicolored displays is in preparation and is scheduled for publication in 1987.

Integrated Ergonomic Models:

An integrated ergonomic model has considerable appeal as a universal tool for the solution of ergonomic design problems. There is a need to assess the current status of human body models and their associated databases, to identify their commonalities and individual as well as general limitations, and to explore if and how these models can be merged and enhanced to serve as convenient tools for the researcher and designer.

The system to be modeled is the human body. For purposes of ergonomic applications it is viewed as a bounded, physical structure with definable geometry and capable of complex kinematic articulated motion, influenced by joint constraints, muscle forces, body inertial properties, external forces and involuntary and cognitive control mechanisms. To properly account for these capabilities, the model must possess certain intrinsic properties. Among these are that it must describe body response in a three dimensional space, the equations for body motion must be dynamic, the model must be constructed of connected segments, each with a locally defined and embedded coordinate system, and it must represent the application of specified forces between segments and between segments and external configurations.

Current methods depend heavily on scalar measures and two dimensional layouts and models. Unfortunately, the transition to three dimensions requires more than a simple extension of these present methods. To properly address motion in three dimensions, spatial kinematics must be adopted for analysis. While doing so increases the complexity of the analysis, this method of analysis has two significant advantages. Joint motion constraints can be introduced as a function of adjacent segment orientation, and segments can have anatomical or geometrical structure for force application and muscle attachment.

The most general equations that can be written for gross body motion are those for describing rigid body dynamics for multiple coupled bodies. The transition to a three dimensionally structured model would allow the superimposition of three dimensional surface shapes and would lead to more precise analysis of body and surrounding configuration interaction and the graphical display of the body.

While these model enhancements will not produce the ultimate totally integrated model, they represent substantial progress towards integrating a number of methodologies currently in use. The point to point and circumferential measurements traditionally made by anthropometrists are consistent with this method, two dimensional analyses fall out by plane projection, static force calculations are part of the dynamic equations if motion is not induced, and link lengths are embedded in the segment joint-center-to-joint-center distances.

A seminar was convened to assess the feasibility of developing human ergonomic models or modules that can be used to integrate biomechanical, anthropometric, and human-equipment interaction data into a basic dynamic model of human characteristics and motor capabilities. Current models were reviewed as benchmarks and research recommendations for the development of an integrated ergonomic model have been prepared in a report scheduled for publication in 1987.

Mental Models:

A central working principle in cognitive psychology is that decisions and actions of a user of a software intensive system depend on that user's mental model of the system. The mental model includes not only the functional characteristics of the system, but its current state, dynamic properties, and reliability.

Describing a mental model is complex by virtue of the fact that significantly different mental models may be generated by the several individuals interacting with the same software. Therefore, it is necessary to distinguish, for example, the designer's model (the designer's conception of his/her own software) from the analyst's model (the understanding the analyst develops of what the user knows about the software). There is also a prescriptive sense of the designer's model, that is, the model which the user should acquire and refer to in using the designer's software.

Mental models will also vary according to the sophistication of the user. For example, an advanced programmer's mental model of given software is likely to be quite different from that of the user with no programming experience. Multiple mental models may also co-exist within the same individual. A person who both designs and later uses a system may develop compartmentalized understandings of the system. Analogous distinctions arise if different task environments are considered. The mental model elicited for routine skilled behavior may differ substantively from that generated when an individual is asked to explain why particular causes give rise to particular effects in a software system.

The description of mental models is potentially far more complicated than these simple examples suggest. What is crucial is not to enumerate every possible model, but to recognize the specific focus and inherent limitations of any particular description of mental models. At present, there is no satisfactory method for describing mental models or characterizing the differences in mental models at varying levels of user expertise or among a population of users.

The development of mental model theory is a major thrust in software human factors research, and, as such, is a driving force in software design. The basis for this impact needs to be analyzed for better focus of further developments in the study of mental models. Consequently the committee conducted a two-day workshop to determine means for achieving a better understanding of mental models and their implications for systems and

software design. The participants at the workshop assessed current conceptualizations of mental models, identified research approaches and needs relevant to developing descriptions of mental models, and suggested appropriate methods for applying knowledge of mental models in the systems design and training processes. The report of the proceedings of this workshop is in preparation and is scheduled for publication in FY 1986.

Distributed Decision Making:

Behavioral decision theory has been used to develop aids which can help experienced decision makers select among alternatives by mental processes that analyze the salient features of a situation, consider the various ranges of interpretations and actions, evaluate the consequences of each alternative, and select appropriate responses. The most promising approaches appear to be based on a mixture of prescriptive and descriptive research. The former asks how people should make decisions, while the latter asks how they actually do make them. In combination, these two research approaches attempt to build from people's decision making strengths, while compensating for their weaknesses. The underlying premise is that significant decisions should seldom be entrusted entirely either to unaided intuition or to automated procedures. Finding the optimum division of labor requires an integrated program of theoretical and empirical research.

Modern command-and-control systems represent a special case of a more general phenomenon, in which the information and authority for decision making are distributed over several individuals or groups. Distributed

decision making systems can be found in such diverse settings as military organizations, voluntary organizations, multinational corporations, diplomatic corps, government agencies, and couples managing a household. Viewing any distributed decision making system in this broader context helps to clarify its special properties.

A general task analysis of distributed decision making systems is developed by detailing the performance issues that accrue with each level of complication as one goes from the simplest situation (an individual intuitively pondering a static situation with complete information) to the most complex (heterogeneous, multiperson systems facing dynamic, uncertain and hostile environments which threaten the communication links and personnel in their system). Drawing from the experience of different systems and from research in areas such as behavioral decision theory, psychology, cognitive science, sociology, and organizational development, the analysis suggests both problems and possible solutions. It also derives some general conclusions regarding the design and management of such systems as well as the asymptotic limits to their performance and the implications of those limits for an organization and overall strategy.

Many civilian, military, and space systems consist of physically separated components which are linked through telecommunications networks and act semiautonomously but cooperatively toward common goals. To enhance flexibility and independence and to take best advantage of local information there is an increasing trend to distribute decision making authority among system components. Of critical importance is

understanding the fundamental requirements which must be met to enable individuals within different organizational components to make decisions effectively and cooperatively with only partial sharing or availability of information. Design of system architecture, decision making protocols, and information support networks will all require knowledge about human decision processes in distributed systems.

A report, based in part on position papers submitted by workshop participants and on the proceedings of the workshop, is in progress. This report, which will delineate recommendations for fundamental research studies in distributed decision making, is scheduled for completion 1987.

Expert Systems:

Expert systems, a branch of artificial intelligence, include a core of specialized knowledge and a prescriptive or descriptive method for acquiring, utilizing, and interpreting that knowledge. There is considerable interest in understanding the structure of expert systems, how to build them, and what they tell us about the nature of expertise. Research is needed to discover methods for learning what the expert's core of knowledge is, what heuristics or rules govern the utilization of this knowledge to solve particular classes of problems, and how best to convey the knowledge to a non-expert user of the system.

The Research Briefing Panel on Cognitive Science and Artificial Intelligence of the National Academy of Sciences has cited expert systems

research as an important topic. Related research topics involve exploring the nature of intelligence and its development from primitive cognitive functions; solving complex problems by developing computer systems which have intellectual, perceptual, and learning abilities; using computers' increasing speeds of data processing and extended memory; and combining an understanding of the way humans learn and perform cognitive tasks with intelligent systems. A method is needed to provide for increased expertise by integrating knowledge and search processes into a single system.

An important human factors issue in the domain of expert systems is how to find out what the expert knows; that is, both the knowledge base itself and the problem solving processes which relate to that knowledge. What rules do experts use to understand and retrieve appropriate subsets of their knowledge base? Should they be asked to describe what they know and the cognitive processes they use? Should they be observed and their activities recorded in settings where they apply their knowledge? Are new and quite different approaches required to gain access to the expert's knowledge and problem solving techniques?

A second critical human factors issue is how best to present the resident information to the user of an expert system. Because novices frequently do not think in the same terms as an expert, attention must be given to translations or explanations of the information. Furthermore, while in some cases a simple answer to a problem is sought from the system, other situations may demand a tutorial. Determining how to pass expertise on to the non-expert is central to human factors research on expert systems.

A two-day workshop focused on function allocation, knowledge acquisition, tutorial, and human-machine interface aspects of expert systems. The report of the proceedings of this workshop is in progress and is scheduled for completion in 1987.

Aging:

With the median age of the general population increasing, understanding the ramifications of the normal aging process has assumed growing importance. In the course of aging, changes occur in the levels of physiological and psychological functioning. Functional capabilities will determine to a large extent how well older persons can perform in the home, workplace and community. Although some work has been done to encourage alterations in these environments to accommodate the aging individual, adequate quantitative data are lacking to describe the effects of functional changes on the activities of an aging population.

The committee has prepared a study plan that will identify and analyze tasks typically encountered in transportation, home, workplace, leisure, and safety/security activities. These task will be reviewed in the context of changes in sensory/perceptual, physical/psysiological, and cognitive/psychomotor functioning that are an integral part of the aging process. For example, decrements in audition can limit communication; declining visual functioning can affect the ability to read, drive a vehicle, or perform work related tasks. Certain systemic changes can limit independent functioning due to decreases in strength, agility, and endurance. Difficulties in learning and retrieving information can have a

negative impact on work performance. In addition more rigid attitudes and reduced motivation toward change may affect other functional capabilities.

Applying system and task analysis methodology to the jobs and activities of the aging and comparing the capabilities of older persons to task demands can help provide an empirical rationale for research required to maintain or enhance the functional capabilities of the aging. With this goal in mind, a study panel will convene in 1987 to identify and recommend basic human factors research needed to effectively use the talent resident in the aging work force and to improve the quality of life of older persons in the home and in the community. Completion of the study and the report is scheduled for early 1988.

Productivity in Information Work:

The demand for qualified personnel to work in the information field has increased to the point where the number of workers in this area exceeds all other workers in the United States. According to 1983 U.S. Department of Labor statistics, about half of the information workers are in the executive, managerial, professional, and technical fields.

Software development, one aspect of information work, involves many tasks including requirements specification, design, coding, testing, defect removal, maintenance, documentation, and project management and usually involves teams of people. One of the few objective measures of software development is lines of code produced. However, this is a poor indicator of effectiveness since it does not relate end user benefit to cost.

Productivity is difficult to define and even more difficult to measure in the information sciences and at the professional and managerial levels. In information software engineering, for example, Boehm (Boehm, Barry, Software Engineering Economics, Prentice Hall, 1981) developed a predictive model for person months and elapsed time for software development starting with the initial analyses and design and ending with final interpretation and test. He identified 15 key factors that affected effort and time and quantified each factor based on actual experience. Thus, his model predicts the quantitative productivity of a software programming team. However, except for Boehm, the extensive literature available on productivity is focused primarily on micro concerns with little attention paid to more general issues.

A steering group has been assigned to determine the feasibility of studying these issues, and if warranted, to plan and organize a workshop. Issues for consideration would include useful methods for measuring and enhancing productivity, cognitive factors related to knowledge acquisition and transfer, software reusability, and organization of software development tasks.

REPORTS

Prior reports prepared by the Committee on Human Factors:

(These reports are summarized in Appendix C)

Research Needs in Human Factors (1983)

Research Needs on the Interactions Between Information Systems and
Their Users (1984)

Research Issues in Simulator Sickness (1984)

Research and Modeling of Supervisory Control Behavior (1984)

Methods for Designing Software to Fit Human Needs and Capabilities (1985)

Human Factors Aspects of Simulation (1985)

Recommendations for Content Revision and Alternate Delivery Modes for
the Human Engineering Guide to Equipment (a letter report) (1985)

Reports scheduled for publication in 1987:

(These studies are summarized in the earlier text)

Human Performance Modeling

Mental Models in Human Computer Interaction: Research Issues About
What the User of Software Knows

Toward the Development of Integrated Ergonomic Models

Research Needs in Multicolored Displays

Theoretical Issues in Distributed Decision Making

Human Factors in Expert Systems

APPENDIX A

COMMITTEE ON HUMAN FACTORS MEMBERS 1986-1987

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APPENDIX B

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HUMAN FACTORS RESEARCH ISSUES FOR AGING POPULATIONS
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APPENDIX C

REPORTS - 1984-1986

Research Needs on the Interaction Between Information Systems and Their Users: Report of a Workshop (1984):

The use-computer interface may become a limiting factor in the widespread use of automated information systems. The technological growth of computer-based information systems has outpaced our knowledge of the way that users interact most effectively with these systems. Regardless of the efficiency of the internal mechanisms of an information system, its overall effectiveness depends heavily on its compatibility with a human user. This study described (1) the unique characteristics of information systems and predicted trends of future technological development that are likely to affect their character; (2) the human cognitive characteristics most importantly involved in user-information system interaction and identified significant behavioral and cognitive science issues; and (3) provided recommendations for fundamental research most necessary to improve the effectiveness of human-information systems interaction.

The study group noted that there is a paucity of theory-based research on user/information system interaction. The members recommended research needed to provide a better understanding of how people acquire and use computer-based information and the methods they use for searching, filtering, and evaluating information.

The report also recommends research needed to better understand the cognitive effects of programming, to increase the rate of information exchange between people and information systems, to develop user skills, and to assess the impact of technology on jobs and job skills.

Research Issues in Simulator Sickness: Proceedings of a Workshop (1984):

Simulators are used extensively for training and are gaining favor for their contributions to equipment and system design and evaluation. However, their usefulness is compromised when disabling sickness related to their design and operation reduce their effectiveness. There is uncertainty about the etiology of simulator sickness although sensory conflict appears to be the major offender.

The report identified design and operational features of simulators that may lead to occupant malaise and recommended procedures for avoiding or ameliorating these effects.

Determination of causes and processes is recommended as a critical topic for research. Analyses of tasks, head movement, visual display and motion-base variables relative to the incidence of simulator sickness must be investigated. Research is needed to determine the contribution to simulator sickness of such factors as field-of-view size, force vectors, the phase and gain relationship of various sensory processes, and certain oculomotor variables. In addition, to understand the simulator sickness phenomenon, more needs to be known about the underlying neurological mechanisms and about the role of adaptation.

Evaluation of candidate countermeasures should also be a central part of on-going research on simulator sickness. Incremental exposure regimens, certain hand-eye coordination games, and medications used for motion sickness might be effective in the prevention or control of simulator sickness. In addition, there seems a reasonable hope that degrading the update rate of moving stimuli in the simulator display might be sufficient to support training while eliminating simulator sickness. These, and other potential countermeasures require further investigation.

Research and Modeling of Supervisory Control Behavior: Report of a Workshop (1984):

In many modern complex systems, the role of the human operator has changed from directing manual control to that of supervising the functions of automated equipment that, in turn, control a vehicle or process through its own sensors and effectors. The task of the human in these systems requires more monitoring and decision responsibility and reduced direct psychomotor control. Specific issues of research strategies to study supervisory control behavior, approaches to modeling this behavior, and means for real-world validation of research and modeling results were addressed in this study.

The conclusions and research recommendations of this report draw on three major themes: characteristics and analysis of supervisory control systems, selection of modeling approaches and research methods, allocation of tasks between the human and the automated equipment, and improved communications between research investigators and designers of these systems.

The research on supervisory control should center on levels of control, goal setting and seeking, cycles of control and feedback, and trust in the system. It should consider the design flexible operator-system interfaces. The operator must have display and control mechanisms to acquire information necessary to make decisions and to exercise control at any level in the system.

Methods for Designing Software to Fit Human Needs and Capabilities:

Proceedings of the Workshop on Software Human Factors (1985):

Computers are pervasive in civilian and military equipment systems. The compatibility of computer based devices with human users is predominantly dependant upon the characteristics of the software. The report suggests that research needs fall into three categories: new theories, new representations, and new data collection and analysis methods. The report contains a compilation of human factors approaches useful for research, experimental design, and data collection methods on user performance, which provides design information important to software and computer developers.

Research methods considered most likely to produce significant results include representations of the users' understanding of a system, representations of a dialog to convey the design to programmers, more comprehensive task analyses that include memory, perceptual and language considerations as well as timing and error predictions, and hardware advances that allow the collection of logging and metering data for tapping the current use of a system.

Human Factors Aspects of Simulation (1985):

Because of the importance and widespread applications of simulation, and the number of significant behavioral and human factors issues in the design and use of simulators, behavioral issues and problems common to many simulators were identified. The report includes an overview of simulation including a historical perspective.

A major issue in simulation is concerned with the heavy reliance on physical fidelity as the principal determinant of a simulator's ability to serve its intended purpose. At the same time, the importance of the relationship between how a simulator is used and its effectiveness is not fully appreciated. As a consequence of this imbalance of emphasis, simulators are often not as cost-effective as they could be. The contributions that behavioral science and human factors engineering can make to the design and use of simulators are relatively neglected.

Although simulator design and operation could be improved by better use of existing behavioral and human engineering principles, the potential contribution of these fields is limited by the lack of adequate performance measurement methods and well developed human performance models. Objective and automated performance measurement systems would greatly facilitate the derivation of detailed quantitative performance information useful for design, training, and research purposes.

The report makes three fundamental recommendations for research: long-range, comprehensive, and forward-looking research plans should be developed to address persistent and emerging simulation problems; long-range stable funding should be provided to encourage the development of academic bases for simulation research; and research to develop near real-time human performance assessment capability for simulation should be given urgent attention.

Recommendations for the Content Revision and Alternate Delivery Modes of The Human Engineering Guide to Equipment Design (Letter Report 1985):

The Human Engineering Guide to Equipment Design (HEGED) was developed to assist designers, engineers, human factors specialists and others in the understanding and application of human engineering principles. Since its last revision in 1972, extensive new, relevant data has been generated. The wide array of users require access to data at differing levels of detail. The study reviewed the scope of the contents of the Guide and the best means for accessing the data in light of current technology. The present book format cannot easily meet the needs for each application, accommodate different users' requirements for level of detail, nor be modified to include later data as it becomes available. The letter report recommends revising the Guide format so that it can be used in an interactive computer system which allows flexibility in terms of access strategy and level of detail, suggests additional areas of content consistent with advances in information technology, and recommends the initiation of modern data delivery systems using interactive computer methods.